Adapting small-scale agriculture to climate change in West Africa

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The importance of family farming

- Family farmers produce 80% of world’s food.
- Family farming is the biggest employer in the world (two thirds of the population in Africa)
- 60% smaller than one hectare (20% of farm land)
- Climate variability and extreme events are among the main factors behind the recent rise in global hunger.
- UN Water Decade of family farming 2019-2028.
• West Africa region is particularly threatened by climate change.

• Dependence on rainfed (irrigation only 3% )

• Small-scale irrigation accounts for the majority of irrigated area.

• Climate change presents an additional challenge for family farmers.
Why this project?

- There is still major knowledge gaps in climate change impact studies on small-scale agriculture in Africa.
- New approaches are required to incorporate climate change adaptation in rural development programs.
Countries selected

Côte d’Ivoire, Gambia, Mali, Niger

- Representativeness of agro-ecological zones
- Climatic risks
- Poverty levels
Methodological approach

Analysis of observed climate and climate projections: Partnership with Agrhymet

Climate change impact
Crop yields in irrigated and rainfed system

Adaptation strategies
Assessment

Resilience assessments
SHARP tool

Cost-benefit analysis
CLIMATE TRENDS IN THE STUDY AREA
Rainfall distribution

Sahel

Soudano - Sahel

Soudanienne

8 Project sites

[200, 400] mm/year

[600, 900] mm/year

[900, 1800] mm/year
ANNUAL RAINFALL VARIABILITY

Observed Rainfall

<table>
<thead>
<tr>
<th>Sites</th>
<th>Precipitation (mm/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bouake</td>
<td>1000-1100</td>
</tr>
<tr>
<td>Kerewan</td>
<td>1100-1200</td>
</tr>
<tr>
<td>Kita</td>
<td>1000-1100</td>
</tr>
<tr>
<td>Maradi</td>
<td>900-1000</td>
</tr>
<tr>
<td>Sapu</td>
<td>1200-1300</td>
</tr>
<tr>
<td>Tahoua</td>
<td>1300-1400</td>
</tr>
<tr>
<td>Yakro</td>
<td>1400-1500</td>
</tr>
<tr>
<td>Zinder</td>
<td>1500-1600</td>
</tr>
</tbody>
</table>
ANNUAL RAINFALL TREND

Trend strongly depend on the location not based on climatological zone.
ANNUAL MEAN TEMPERATURE VARIABILITY
ANNUAL MEAN TEMPERATURE TREND

Strong to moderate increase of Temperature is observed.

Better use a long time serie 30 years) of data to see the magnitude of the increase.
CLIMATE PROJECTIONS
Region 4: CORDEX_AFRICA

Coordinated Regional Climate Downscaling Experiment (CORDEX)

<table>
<thead>
<tr>
<th>RCMs</th>
<th>Countries</th>
<th>Labels</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCA4 (CanESM2)</td>
<td>Canada</td>
<td>CCCma</td>
</tr>
<tr>
<td>RCA4 (CNRM-CM5)</td>
<td>France</td>
<td>CNRM</td>
</tr>
<tr>
<td>RCA4 (EC-EARTH)</td>
<td>Europe</td>
<td>ICHEC</td>
</tr>
<tr>
<td>RCA4 (MIROC5)</td>
<td>Japan</td>
<td>MIROC</td>
</tr>
<tr>
<td>RCA4 (HadGEM2-ES)</td>
<td>UK</td>
<td>MOHC</td>
</tr>
<tr>
<td>RCA4 (MPI-ESM-LR)</td>
<td>Germany</td>
<td>MPI</td>
</tr>
<tr>
<td>RCA4 (NorESM1-M)</td>
<td>Norway</td>
<td>NCC</td>
</tr>
<tr>
<td>RCA4 (GFDL-ESM2M)</td>
<td>USA</td>
<td>NOAA</td>
</tr>
<tr>
<td>RCA4 (CSIRO MK2)</td>
<td>Australia</td>
<td>CSIRO</td>
</tr>
<tr>
<td>RCA4 (IPSL-CM1-4)</td>
<td>France</td>
<td>IPSL</td>
</tr>
</tbody>
</table>
Climate change scenarios

Source: CSIRO

Today 2030 2050

pessimistic moderate
### Selected RCMs

<table>
<thead>
<tr>
<th>COUNTRIES</th>
<th>SITES</th>
<th>RCM Labels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NIGER</strong></td>
<td>Maradi</td>
<td>CCCma, CNRM, MPI</td>
</tr>
<tr>
<td></td>
<td>Tahoua</td>
<td>CNRM, MPI, MOHC</td>
</tr>
<tr>
<td></td>
<td>Zinder</td>
<td>CNRM, MPI, MOHC</td>
</tr>
<tr>
<td><strong>GAMBIA</strong></td>
<td>Kerewan</td>
<td>CNRM, MIROC, MPI</td>
</tr>
<tr>
<td></td>
<td>Sapu</td>
<td>CNRM, MIROC, MPI</td>
</tr>
<tr>
<td><strong>MALI</strong></td>
<td>Kita</td>
<td>CCCma, CNRM, MPI</td>
</tr>
<tr>
<td><strong>COTE D’IVOIRE</strong></td>
<td>Yakro</td>
<td>CCCma, CNRM, IPSL</td>
</tr>
</tbody>
</table>
**ANNUAL RAINFALL CHANGE FOR RCP4.5 – Moderate scenario**

- High variability in rainfall changes is expected
- Rainfall changes average -5% to 5% (H2030) and -10% to 10% (H2050)
CLIMATE PROJECTION

ANNUAL MEAN TEMPERATURE CHANGE FOR RCP45 AND RCP85

- **RCP45**
  - Period: 2021-2040
  - Sites: Bouake, Kerewan, Kita, Maradi, Sapu, Tahoua, Yakro, Zinder

- **RCP85**
  - Period: 2021-2040
  - Sites: Bouake, Kerewan, Kita, Maradi, Sapu, Tahoua, Yakro, Zinder

- **RCP45**
  - Period: 2041-2060
  - Sites: Bouake, Kerewan, Kita, Maradi, Sapu, Tahoua, Yakro, Zinder

- **RCP85**
  - Period: 2041-2060
  - Sites: Bouake, Kerewan, Kita, Maradi, Sapu, Tahoua, Yakro, Zinder

Adapting irrigation to climate change.
## CLIMATE SCENARIOS

| CLIMATE | RCP45 |  | RCP85 |  |
|---------|-------|  |-------|  |
|         | Horizon 2030 | Horizon 2050 | Horizon 2030 | Horizon 2050 |
| **PCP (%)** | -5% to 5% | -10% to 10% | -8% to 8% | -16% to 16% |
| **T (°C)**  | 0.9 to 1.5 | 1.3 to 2.3 | 1.0 to 1.7 | 1.7 to 3 |
| **ET (%)**  | 2% to 4.5% | 3% to 6.5% | 2.5% to 5.5% | 4.5% to 8% |

ET=evapotranspiration, PCP=precipitation, T=temperature

The period 1986-2005 has been used as reference period to compute the relative changes of the annual mean for the three climate variables (ET, PCP and T). In this summary, all sites and RCMs have been used to capture the range of variability.
In Summary

- **Temperatures** expected to increase, greater increase in the Sahel. Temperature increases from **0.7°C to 2.4°C** for RCP 4.5 and between **0.9°C and 3.2°C** for RCP 8.5. The increase in temperature higher in H50 than in H30.

- No clear trend in **precipitation** changes. Relative change between -10 to 10 percent in a moderate scenario (RCP 4.5), and -16 percent to 16 in a pessimistic scenario (RCP 8.5). The variability of precipitation changes is higher in the Sahel zone. Precipitation changes are expected to increase from H30 to H50.

- Increase in evapotranspiration (ET) with the greatest increase in the Sahel. A relative change between **1.5 percent and 8 percent** is for RCP 4.5 and between **2 percent to 10 percent** for RCP 8.5. The highest changes are expected for H50.
crops and cultivation methods

- Tomato
- Rice
- Maize
- Sorghum

- Irrigated
- Rainfed
Combinations of crops, cultivation method and sites.
Simulation of crop yields

- Climate
  - Historical data
  - Horizon 2030 (RCP 4.5)
  - “ 2030 (RCP 8.5)
  - Horizon 2050 (RCP 4.5)
  - “ 2050 (RCP 4.5)

- Crop
- Irrigation or rainfed
- Soil
- Management

Yield and Biomass

Crop Simulation of crop yields

- Historical data
- Horizon 2030 (RCP 4.5)
- “ 2030 (RCP 8.5)
- Horizon 2050 (RCP 4.5)
- “ 2050 (RCP 4.5)

- AquaCrop
  - Evapotranspiration (ET)
  - Rainfall (P)
  - Irrigation (I)
  - Deep percolation (DP)
  - Capillary rise (CR)
  - Threshold
  - Field capacity
  - Stored soil water (mm)
Effect of climate change on crop production

- Increased air temperature
- Increased evapotranspiration (ETo)
- Rainfall pattern: altered & less predictable, more extreme events (droughts & floods)

Most likely negative effect (due to more water stress)

- Increase of atmospheric CO$_2$ concentration

Positive effect (due to CO$_2$ fertilisation)

The combined effect of CO$_2$ fertilization and altered weather conditions

Positive or negative depends largely on the irrigation and soil fertility management

Studied with AquaCrop

Adapting irrigation to climate change
1. Business as usual
2. Adaptation strategy
3. Optimal conditions

Generated set of daily data for 20 years

- Historical data
- Horizon 2030 (RCP 4.5)
- " 2030 (RCP 8.5)
- Horizon 2050 (RCP 4.5)
- " 2050 (RCP 4.5)
Summary of relative yield change

Combined effect of CO₂ fertilization and altered weather conditions

Relative yield change for rainfed sorghum

Current soil fertility

Adapting irrigation, fertilization
The diagram illustrates a generated set of daily data for 20 years under different climate conditions and soil management strategies. The climate conditions include historical data and projections for the horizon years 2030 (RCP 4.5) and 2030 (RCP 8.5). Soil conditions are assessed with stored soil water levels representing field capacity, threshold, and wilting point. Irrigation and rainfall are depicted as inputs to the system, with evapotranspiration (ET) and deep percolation (DP) as outputs.

The soil management strategies are categorized into three options:

1. **Business as usual (current soil fertility)**
2. **Adaptation strategy – Improved fertility**
3. **Optimal conditions**

These strategies aim to optimize crop productivity under varying climate and soil conditions.
Summary of relative yield change

Maize (C4 crop): less effect of CO₂ fertilization

Improved soil fertility

Current soil fertility

Adapting irrigated and rainfed agriculture to changing climate

Relative yield change (%)

Yield change for various crops and years:
- Maize in 2030 and 2050
- Rice in 2030 and 2050
- Corn in 2030 and 2050

Irrigated and rainfed conditions compared.
Generated set of daily data for 20 years

- Historical data
- Horizon 2030 (RCP 4.5)
- " 2030 (RCP 8.5)
- Horizon 2050 (RCP 4.5)
- " 2050 (RCP 4.5)

1. Current conditions (reduced soil fertility)
2. Adaptation strategy (improved soil fertility)
3. Optimal conditions
Summary of relative yield change

- Optimal management conditions
- Huge potential (yield can double)
- Improved soil fertility
- Current soil fertility

Relative yield change (%)

Irrigated vs. rainfed conditions

- Tomato
- Rice
- Maize

0% yield change
In summary:

- Under current management practices, climate change will have a negative impact on agricultural production. On average, yield is expected to decline from 5 percent to 20 percent, depending on the crop and the agroecological zone. Higher declines are likely among long-cycle cultivars of rainfed crops in the Soudanian zone.

- The current cultivars of sorghum in the Sahel zone may no longer be feasible with climate change.

- Adopting water and soil management practices can allow smallholders to adapt to the negative impacts. Results show that improving the soil fertility by at least 15 to 20 percent could lead to an increase in crop yields of 8 percent for C3 crops (e.g. tomato and rice).

- Supplementing rainfed agriculture with irrigation as a strategy to enhance yields can only be effective with the improvement of soil fertility.

- In future climate change scenarios, crops can benefit from increased CO with improved if soil conditions are improved.
Limitations

- Losses due to **pest and diseases** might increase in future climatic conditions;
- Simulations were done with the current cultivars. **Other cultivars/crops** (difference in crop cycle length, stress tolerance, harvest index, ...) might be more suited;
- **Acclimatization** in which the current cultivars adjusts to the changes in the climate conditions are not considered;
- **Mixed cropping** such as for sorghum was not simulated.
Climate change impacts and responses in small-scale irrigation systems in West Africa
Case studies in Côte d'Ivoire, The Gambia, Mali and Niger

Adapting small-scale irrigation to climate change in West and Central Africa (AICCA)

Thank you